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WIND-TUNNEL INVESTIGATION OF AN NACA 23021 AIRFOIL WITH TWO SIZES OF BALANCED SPLIT FLAPS

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NACA

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SUMMARY

An investigation has been made in the NACA 7- by 10-foot wind tunnel of a large-chord NACA 23021 airfoil with a 15-percent-chord and a 25-percent-chord balanced split flap of Clark Y profile, to determine the aerodynamic section characteristics of the airfoil-flap combinations as affected by the size, nose location, and deflection of the flaps. Section lift, drag, and pitching-moment characteristics are presented in the form of contours of flap nose location for given values of the lift, drag, and pitching-moment coefficients and complete aerodynamic section characteristics are presented for four representative locations of each flap. The two balanced split flaps are compared with a slotted-flap arrangement developed in a previous investigation.

The optimum aerodynamic arrangement of either balanced split flap, from considerations of minimum profile-drag coefficients for take-off and climb, was an arrangement comparable to the Fowler flap. The 15-percent balanced split flap was better over the moderate lift range, while the 25-percent balanced split flap was better over the high-lift range. Both balanced split flaps were better than the best slotted flap of a previous investigation, except in the high-lift range, where the slotted flap developed a higher maximum lift coefficient than did the 15-percent balanced split flap.

From considerations of maximum lift coefficient, the Fowler arrangement of the 25-percent balanced split flap was the optimum, giving an increment of maximum lift coefficient of about 1.82. The best slotted flap of a previous investigation gave an increment of 1.47, while the Fowler arrangement of the 15-percent balanced split flap gave an increment of 1.24. The optimum position for the 15-percent balanced split flap was a high drag position at 5 percent ahead of the trailing edge and 3 percent below the chord line, where the increment of maximum lift coefficient obtained was 1.31.

In general, under comparable conditions, the previously developed slotted flap had equal or somewhat lower pitching-moment coefficients than either size of balanced split flap.

INTRODUCTION

The National Advisory Committee for Aeronautics has undertaken an extensive investigation of various airfoil-flap combinations to furnish information applicable to the aerodynamic and structural design of high-lift devices with the view toward increasing the safety and performance of airplanes. A high-lift device capable of producing high lift with low drag for take-off and initial climb, and high lift with variable drag for landing is believed desirable. Other important features are: no increase in drag with flaps neutral, small change in pitching moment with flap deflection, low operating forces, freedom from possible icing, and structural simplicity.

Some promising airfoil-flap combinations have been developed for the NACA 23012 and 23021 airfoils. Aerodynamic data for the NACA 23021 airfoil equipped with single slotted flaps are given in references 1 and 2, with split flaps in reference 3, with plain and slotted extensible flaps in reference 4, and with double slotted flaps in reference 5. Structural data on this airfoil equipped with a single slotted flap and with a split flap are given in reference 6.

The type of flap most commonly used on modern airplanes is some form of split flap. In order to furnish information on this type of flap, an investigation has been made of an NACA 23012 airfoil equipped with two sizes of balanced split flaps, and is reported in reference 7. The investigation of balanced split flaps has been extended to the thicker NACA 23021 airfoil and the results are presented herein. By a balanced split flap is meant a split flap of airfoil section which is displaced rearward as well as deflected downward.

APPARATUS AND TESTS

Models

The basic airfoil used in the tests was built to the NACA 23021 profile with a chord of 3 feet and a span of

7 feet; the ordinates for the section are given in table I. Two sets of laminated mahogany blocks were used as removable tail pieces for the airfoil, one for each of the flaps tested. The blocks were cut out as shown in figure 1 so that, in the retracted position, the flaps faired smoothly into the wing.

The two flaps tested were built to the Clark Y profile (ordinates table I). The flap chords were, respectively, 15 and 25 percent of the main airfoil chord and were of the same span as the airfoil. The flaps were built of laminated mahogany and were attached to the main airfoil with special fittings. These fittings allowed a wide variation in the location of the nose point of each flap and permitted flap deflections of from 0° to 60° in 10° increments at each location. Figure 1 shows the location of the nose points tested. The nose point of the flap is defined as the point of tangency of the flap leading-edge arc with a line perpendicular to the flap chord. The models were made to a tolerance of ±0.015 inch.

Tests

The model was mounted in the closed test section of the NACA 7- by 10-foot wind tunnel, so that it completely spanned the jet except for small clearances at each end (references 8 and 9). The main airfoil was rigidly attached to the balance frame by torque tubes which extended through the upper and the lower boundaries of the tunnel. The angle of attack of the model was set from outside the tunnel by rotating the torque tubes by means of a calibrated drive. Since approximately two-dimensional flow is obtained with this type of installation, the section characteristics of the model under test may be determined.

A dynamic pressure of 16.37 pounds per square foot was maintained for all tests, which corresponds to a velocity of about 80 miles per hour under standard conditions, and to a test Reynolds number of about 2,190,000 based on the chord of the airfoil with the flap retracted. The effective Reynolds number was about 3,500,000 based on a turbulence factor of 1.6 for the tunnel. (See reference 8.)

Force tests were made with each flap located in the positions shown in figure 1 and for flap deflections from 0° to 60° in 10° increments. Lift, drag, and pitching moment were measured through the angle-of-attack range from -6° to the stall.

RESULTS AND DISCUSSION

Coefficients

All test results are given in standard nondimensional section coefficient form corrected as explained in reference 8.

c_l section lift coefficient (l/qc)

c_{d_o} section profile-drag coefficient (d_o/qc)

$c_{m_{(a.c.)_o}}$ section pitching-moment coefficient about aerodynamic center of plain airfoil $\left(m_{(a.c.)_o}/qc^2\right)$

where

l section lift

d_o section profile drag

$m_{(a.c.)_o}$ section pitching moment

q dynamic pressure $(\frac{1}{2}\rho V^2)$

c chord of basic airfoil with flap retracted

and

α_o angle of attack for infinite aspect ratio

δ_f flap deflection measured between the airfoil chord line and the flap chord line

Precision

The accuracy of the measurements in the tests is believed to be within the following limits:

α_o - - - - - - ± 0.1 $c_{d_{o(c_l=1.0)}}$ - - - - - - ± 0.0006

$c_{l_{max}}$ - - - - ± 0.03 $c_{d_{o(c_l=2.5)}}$ - - - - - - ± 0.002

$c_{m_{(a.c.)_0}}$ - - - ±0.003 δ_f - - - - - - - - - - - - ±0.2°

$c_{d_{0_{min}}}$ - - - - - ±0.0003 Flap position - - - - ±0.001c

No corrections have been applied to the data for the effect of flap hinges, as their effect is believed to be small. The relative merits of the various flap combinations are probably not appreciably affected because the same hinge fittings were used in all tests.

No attempt was made to determine the effect of the break in the lower surface of the wing when the flap is retracted, as it is believed that some comparatively simple arrangement may be used to seal the break on an actual installation.

Plain Airfoil

The complete aerodynamic section characteristics of the plain NACA 23021 airfoil are given in figure 2. These data are presented and discussed in reference 1.

Determination of Optimum Flap Arrangements

Maximum lift.- Contours of flap nose location for maximum lift coefficient are presented in figure 3 for the 15-percent-chord balanced split flap. The optimum locations of the flap nose are directly below the trailing edge of the airfoil for flap deflections less than 25°; for which deflections, based on information obtained from previous investigations of low drag arrangements, the flap was unstalled. (Note that this is the Fowler or the slotted extensible flap arrangement.) The best nose location was 6 percent below the chord line for 0° flap deflection, 3 percent below for 10° flap deflection, and 1.5 percent below for 20° to 25° flap deflections. After the flap stalls the optimum location is 5 percent ahead of the trailing edge and 3 percent below the chord line for all flap deflections from 30° to 60°. The maximum lift coefficient, obtained with the flap located at the Fowler position and with the comparatively low drag flap deflection of 25°, was 2.54 which was only increased to 2.59 at a flap deflection of 60°. The maximum lift coefficient obtained with the 15-percent-chord balanced split flap at the optimum location was 2.66 with a flap deflection of 60° as compared to the maximum lift coefficient of 2.82 obtained with the 25.66-percent-chord slotted flap 2b of reference 1.

The contours of flap location for maximum lift coefficient for the 25-percent-chord balanced split flap are presented in figure 4. As for the smaller flap, the optimum locations for the unstalled flap deflections are below the trailing edge of the airfoil, being 6 percent below the chord line for 0° deflection, 3 percent below for 10° and 20° deflections, from 3 to 1.5 percent below for a 30° deflection, and 1.5 percent below the chord line for a 40° flap deflection. Note that the larger flap went to a much higher deflection before it stalled. The best locations for the 50° and 60° flap deflections were 3 percent below the chord line and $8\frac{1}{3}$ percent ahead of the trailing edge. The maximum lift coefficients obtained were 3.16 at 40° deflection and 3.00 at 60° deflections, so there is no reason to use the higher deflections unless added drag for landing is desired along with a sacrifice of maximum lift coefficient.

From the contours given in figures 3 and 4 the designer can determine the maximum lift coefficient to be expected at any flap location and deflection within the range investigated. The contours do not all close but it is believed that a sufficient range was investigated to cover any probable installation.

<u>Minimum profile drag</u>.- The contours of flap nose location for constant profile-drag coefficients for the 15-percent-chord balanced split flap are presented in figures 5, 6, and 7. The contours are given for lift coefficients of 1.0, 1.5, and 2.0 for each flap deflection from 0° to 60°. The minimum profile-drag coefficient obtained at a lift coefficient of 1.0 was 0.0218 for the Fowler arrangement deflected 10° as compared to a profile-drag coefficient of 0.0248 for the plain wing. At a lift coefficient of 1.5, the Fowler arrangement deflected either 10° or 20° gave a minimum profile-drag coefficient of 0.0306, and at a lift coefficient of 2.0 the Fowler arrangement deflected 20° was also the optimum, giving a minimum profile-drag coefficient of 0.0446. The Fowler arrangement of the 15-percent-chord balanced split flap has a lower profile drag than slotted flap 2b of reference 1 for all lift coefficients below 2.0, but has higher profile-drag coefficients at lift coefficients above 2.0.

The contours of flap nose location for constant profile-drag coefficients for the 25-percent-chord balanced split flap are presented in figures 8, 9, and 10. The optimum location of the nose of the flap for a lift coefficient of 1.0 was 3 percent below the chord line and $8\frac{1}{3}$ percent ahead of the trailing edge at 10° deflection for the 25-percent-chord flap. However, the minimum profile-drag coefficient of 0.0231 was only increased to 0.0237 when the flap was moved back to the Fowler position. Both arrangements are better than either the plain airfoil or slotted flap 2b of reference 1, but are inferior to the optimum arrangement of the 15-percent-chord balanced split flap. The Fowler arrangement was the optimum at a lift coefficient of 1.5, and the profile-drag coefficient was the same as for the 15-percent-chord balanced split flap at the same lift coefficient. At a lift coefficient of 2.0, the optimum arrangement was the Fowler, deflected 20°. The profile-drag coefficient of 0.0405 obtained was lower than that of either slotted flap 2b of reference 1 or the 15-percent-chord balanced split flap. The 25-percent-chord balanced split flap located at the Fowler position had a minimum profile-drag coefficient of 0.064 at a lift coefficient of 2.5 as compared to a profile-drag coefficient of 0.083 for slotted flap 2b of reference 1 and 0.110 for the 15-percent-chord balanced split flap at the Fowler position.

The location of the nose of the flap for either balanced split flap for minimum profile-drag coefficients is not extremely critical, but the drag does increase rather rapidly as the flap nose is moved forward or downward from the optimum position. The optimum arrangement is one comparable to the Fowler flap from considerations of minimum profile-drag coefficients.

Pitching moment.- The contours of flap nose location for pitching-moment coefficients about the aerodynamic center of the plain airfoil are presented in figures 11 to 16 for both sizes of balanced split flaps. In general, the optimum location of the flaps to give minimum pitching-moment coefficients at a given lift coefficient and flap deflection is the simple split-flap arrangement, while the location which gives the maximum pitching-moment coefficients is the Fowler arrangement. For the 15-percent-chord balanced split flap the pitching moments for the Fowler arrangement are about 35 percent higher than for the simple split-flap arrangement, and for the 25-percent-chord balanced split flap they are about 90 percent higher for the Fowler arrangement than for the simple split-flap arrangement.

An exact analysis of pitching-moment data is quite complicated and a great many different factors must be considered. In this report the pitching-moment coefficients of the two sizes of balanced split flaps will be compared only on the basis of equal maximum lift coefficients. This comparison is given in the following table for both sizes of balanced split flaps at several locations and for slotted flap 2b of reference 1, all arranged to give a maximum lift coefficient of 2.3 and at lift coefficients of 70, 80, and 90 percent of the maximum lift coefficient. Profile-drag-coefficient and flap-deflection data are included in the table.

			c_{d_0} at			$c_{m_{(a.c.)_0}}$ at		
25-percent-chord balanced split flap, $c_{l_{max}} = 2.3$								
x	y	δ_f for $c_{l_{max}}$	0.9 $c_{l_{max}}$	0.8 $c_{l_{max}}$	0.7 $c_{l_{max}}$	0.9 $c_{l_{max}}$	0.8 $c_{l_{max}}$	0.7 $c_{l_{max}}$
0.0833	0.06	15.5°	0.086	0.075	0.067	-0.295	-0.292	-0.285
.1667	.03	8°	.054	.042	.035	-.313	-.302	-.286
.25	0	10.5°	.055	.044	.036	-.330	-.315	-.305
.25	.015	5°	.058	.042	.035	-.300	-.278	-.260
15-percent-chord balanced split flap, $c_{l_{max}} = 2.3$								
0.05	0.06	28°	0.091	0.082	0.076	-0.288	-0.284	-0.279
.10	.03	20°	.067	.056	.049	-.300	-.300	-.295
.15	0	33°	.067	.055	.047	-.360	-.351	-.349
.15	.015	22°	.050	.041	.035	-.355	-.368	-.352
25.66-percent-chord slotted flap 2b of reference 1, $c_{l_{max}} = 2.3$								
		20°	0.048	0.040	0.035	-0.300	-0.290	-0.280

The table shows that slotted flap 2b of reference 1 has slightly lower pitching-moment coefficients than the 15-percent-chord balanced split flap except for the higher drag arrangement of the balanced split flap, and has approximately the same pitching-moment coefficients as the low-drag arrangements of the 25-percent-chord balanced split flap.

<u>Effect of sealing gap</u>.- Incomplete tests were made with both the 15- and the 25-percent-chord balanced split flaps to determine the effect of sealing small gaps between the airfoil and the flap nose. Results are in agreement with reference 7 where it was found that sealing small gaps of about 1 percent or less was beneficial to the maximum lift coefficient, while sealing gaps greater than about 1 percent was detrimental to the maximum lift coefficient. From this it would appear that the small gaps were acting as leaks while the large gaps were acting as slots; however, it should be noted that in all cases sealing the gap increased the profile-drag coefficient. The data obtained on the effects of sealing the gaps were not sufficient to be presented in the form of curves in this report.

Aerodynamic Section Characteristics

Complete aerodynamic section characteristics are presented in figures 17 to 24 for four different nose locations of both the 15- and the 25-percent-chord balanced split flaps. These locations are believed to lie on or near any probable path taken by the flap in moving from its retracted position to its position for maximum lift. These figures, in conjunction with the contours of figures 3 to 16, should allow the designers to predict the performance of any airfoil-flap arrangement within the range investigated.

Comparison of Flap Arrangements

Envelope polars of profile-drag coefficient for both sizes of balanced split flaps are given in figures 25 and 26, for the four positions for which complete aerodynamic section characteristics were given. These polars show that the Fowler arrangement gives the lowest profile-drag coefficient for a given lift coefficient for either size of flap, except at the maximum lift of the 15-percent-chord balanced split flap, where a higher maximum lift coefficient is obtained with the flap located 5 percent ahead of the trailing edge and 3 percent below the chord line. From consideration of maximum lift coefficient and minimum profile-drag coefficient, the Fowler location is the best for the 25-percent-chord balanced split flap.

From consideration of maximum lift coefficient, the optimum location of the 15-percent-chord balanced split flap is 5 percent ahead of the trailing edge and 3 percent below the chord line; while, from considerations of minimum profile-drag coefficient, the Fowler location is the optimum.

Comparison of Fowler Arrangements of the Balanced Split Flaps and Slotted Flap 2b of Reference 1

Envelope polars for the Fowler arrangements of the two sizes of balanced split flaps and for the 25.66-percent-chord slotted flap 2b of reference 1 are given in figure 27. This figure shows that the basic airfoil had the lowest profile-drag coefficients over the low lift range; the Fowler arrangement of the 15-percent-chord balanced split flap had the lowest profile-drag coefficients over the moderate lift range; and the Fowler arrangement of the 25-percent-chord balanced split flap had the lowest profile-drag coefficients over the high lift range.

The Fowler arrangement of the 25-percent-chord balanced split flap was better than slotted flap 2b of reference 1 over the whole lift range; while the Fowler arrangement of the 15-percent-chord balanced split flap was better than slotted flap 2b over the low and moderate lift ranges, but had higher profile-drag coefficients over the high lift range.

A comparison of the increments of maximum lift coefficient for the two sizes of balanced split flaps at the Fowler position and for slotted flap 2b of reference 1 is given in figure 28. This figure shows that little increase in maximum lift coefficient is obtained by deflecting the balanced split flap beyond the angle at which the flap stalls. The 25-percent-chord balanced split flap gave the largest increment of maximum lift coefficient, about 1.82; slotted flap 2b of reference 1 gave an intermediate increment of maximum lift coefficient, about 1.47; while the 15-percent-chord balanced split flap gave the smallest increment of maximum lift coefficient, about 124.

CONCLUDING REMARKS

The optimum aerodynamic arrangement of either size of balanced split flap, from consideration of minimum profile-drag coefficients for take-off and initial climb, was an arrangement comparable to the Fowler flap. The results showed that the basic airfoil had the lowest profile-drag coefficients over the low lift range; the optimum arrangement of the 15-percent-chord balanced split flap had the lowest profile-drag coefficients over the moderate lift range; and the optimum arrangement of the 25-percent-chord balanced split flap had the lowest profile-drag coefficients over the high lift range. On the basis of low profile-drag coefficients, the optimum arrangement of the 25-percent-chord balanced split flap was better than the best slotted flap, developed in a previous investigation, over the whole lift range, while the optimum arrangement of the 15-percent-chord balanced split flap was better than the previously developed slotted flap over the low and moderate lift ranges, but had higher profile-drag coefficients over the high lift range.

The Fowler arrangement of the 25-percent-chord balanced split flap gave the highest increment of maximum lift coefficient, about 1.82 as compared to 1.47 for the previously developed slotted flap, and 1.24 for the Fowler arrangement of the 15-percent-chord balanced split flap. The optimum arrangement of the 15-percent-chord balanced split flap from considerations of maximum lift coefficient was 5 percent ahead of the trailing edge and 3 percent below the chord line, where the increment of maximum lift coefficient was 1.31.

In general, under comparable conditions, the previously developed slotted flap had equal or somewhat lower pitching moments than either size of balanced split flap.

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REFERENCES

1. Wenzinger, Carl J., and Harris, Thomas A.: Wind-Tunnel Investigation of an N.A.C.A. 23021 Airfoil with Various Arrangements of Slotted Flaps. NACA Rep. No. 677, 1939.

2. Duschik, Frank: Wind-Tunnel Investigation of an N.A.C.A. 23021 Airfoil with Two Arrangements of a 40-Percent-Chord Slotted Flap. NACA TN No. 728, 1939.

3. Wenzinger, Carl J., and Harris, Thomas A.: Wind-Tunnel Investigation of N.A.C.A. 23012, 23021, and 23030 Airfoils with Various Sizes of Split Flap. NACA Rep. No. 668, 1939.

4. Harris, Thomas A., and Swanson, Robert S.: Wind-Tunnel Tests of an NACA 23021 Airfoil Equipped with a Slotted Extensible and a Plain Extensible Flap. NACA TN No. 782, 1940.

5. Harris, Thomas A., and Recant, Isadore G.: Wind-Tunnel Investigation of NACA 23012, 23021, and 23030 Airfoils Equipped with 40-Percent Double Slotted Flaps. NACA Rep. No. 723, 1941.

6. Harris, Thomas A., and Lowry, John G.: Pressure Distribution over an NACA 23021 Airfoil with a Slotted and a Split Flap. NACA Rep. No. 718, 1941.

7. Harris, Thomas A., and Purser, Paul E.: Wind-Tunnel Investigation of an NACA 23012 Airfoil with Two Sizes of Balanced Split Flap. NACA ACR, Nov. 1940.

8. Wenzinger, Carl J., and Harris, Thomas A.: Wind-Tunnel Investigation of an NACA 23012 Airfoil with Various Arrangements of Slotted Flaps. NACA Rep. No. 664, 1939.

9. Harris, Thomas A.: The 7 by 10 Foot Wind Tunnel of the National Advisory Committee for Aeronautics. NACA Rep. No. 412, 1931.

10. Jacobs, Eastman N., and Sherman, Albert: Airfoil Section Characteristics as Affected by Variations of the Reynolds Number. NACA Rep. No. 586, 1937.

TABLE I

Ordinates for Airfoil and Flap Shapes

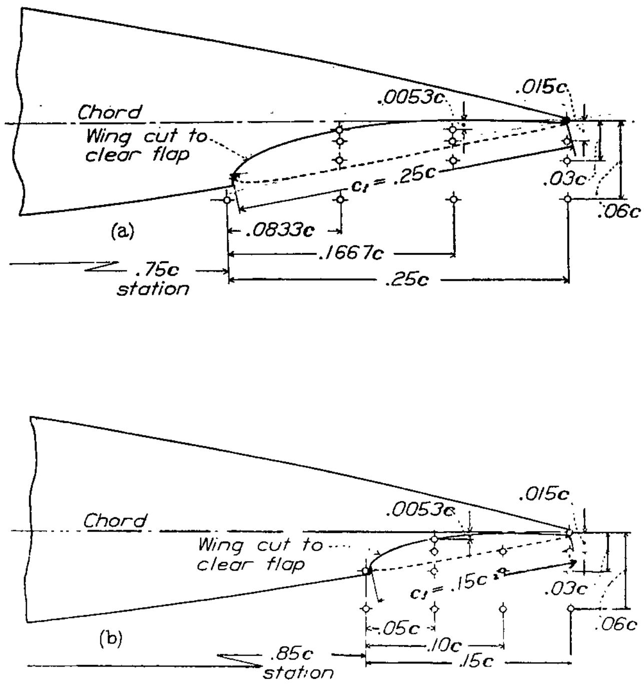
(Stations and ordinates in percent of airfoil chord)

NACA 23021 airfoil		
Station	Upper surface	Lower surface
0	-	0
1.25	4.87	-2.08
2.5	6.14	-3.14
5	7.93	-4.52
7.5	9.13	-5.55
10	10.03	-6.32
15	11.19	-7.51
20	11.80	-8.30
25	12.05	-8.76
30	12.06	-8.95
40	11.49	-8.83
50	10.40	-8.14
60	8.90	-7.07
70	7.09	-5.72
80	5.05	-4.13
90	2.76	-2.30
95	1.53	-1.30
100	.22	-.22

L.E. radius: 4.85
Slope of radius through end of chord: 0.305

Clark Y flaps		
Station	Upper surface	Lower surface
0	3.50	3.50
1.25	5.45	1.93
2.5	6.50	1.47
5	7.90	.93
7.5	8.85	.63
10	9.60	.42
15	10.69	.15
20	11.36	.03
30	11.70	0
40	11.40	0
50	10.52	0
60	9.15	0
70	7.35	0
80	5.22	0
90	2.80	0
95	1.49	0
100	.12	0

L.E. radius:1.50



(a) 0.25c balanced split flap

(b) 0.15c balanced split flap

Figure 1.- The 0.15c and 0.25c balanced split Clark Y flaps on the NACA 23021 airfoil, showing flap nose locations tested.

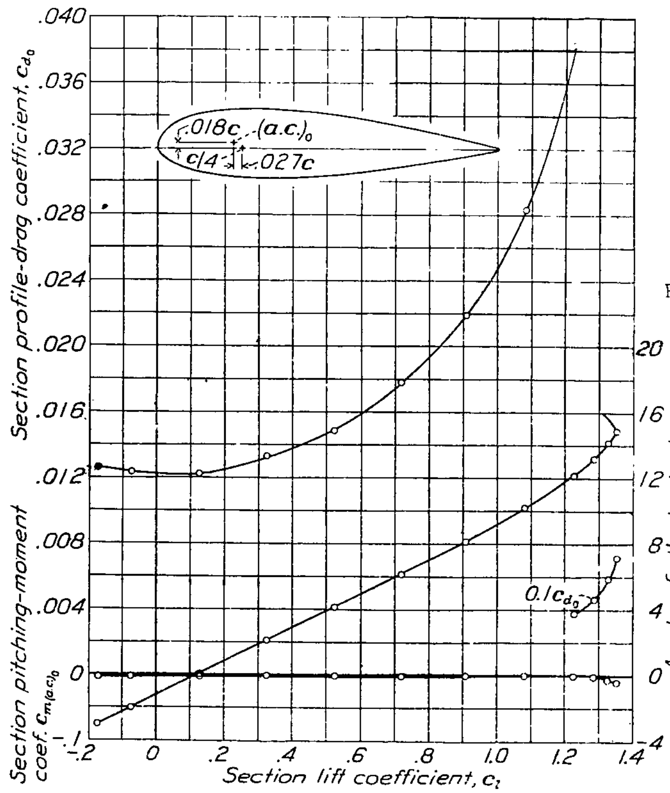


Figure 2.- Aerodynamic section characteristics of NACA 23021 plain airfoil.

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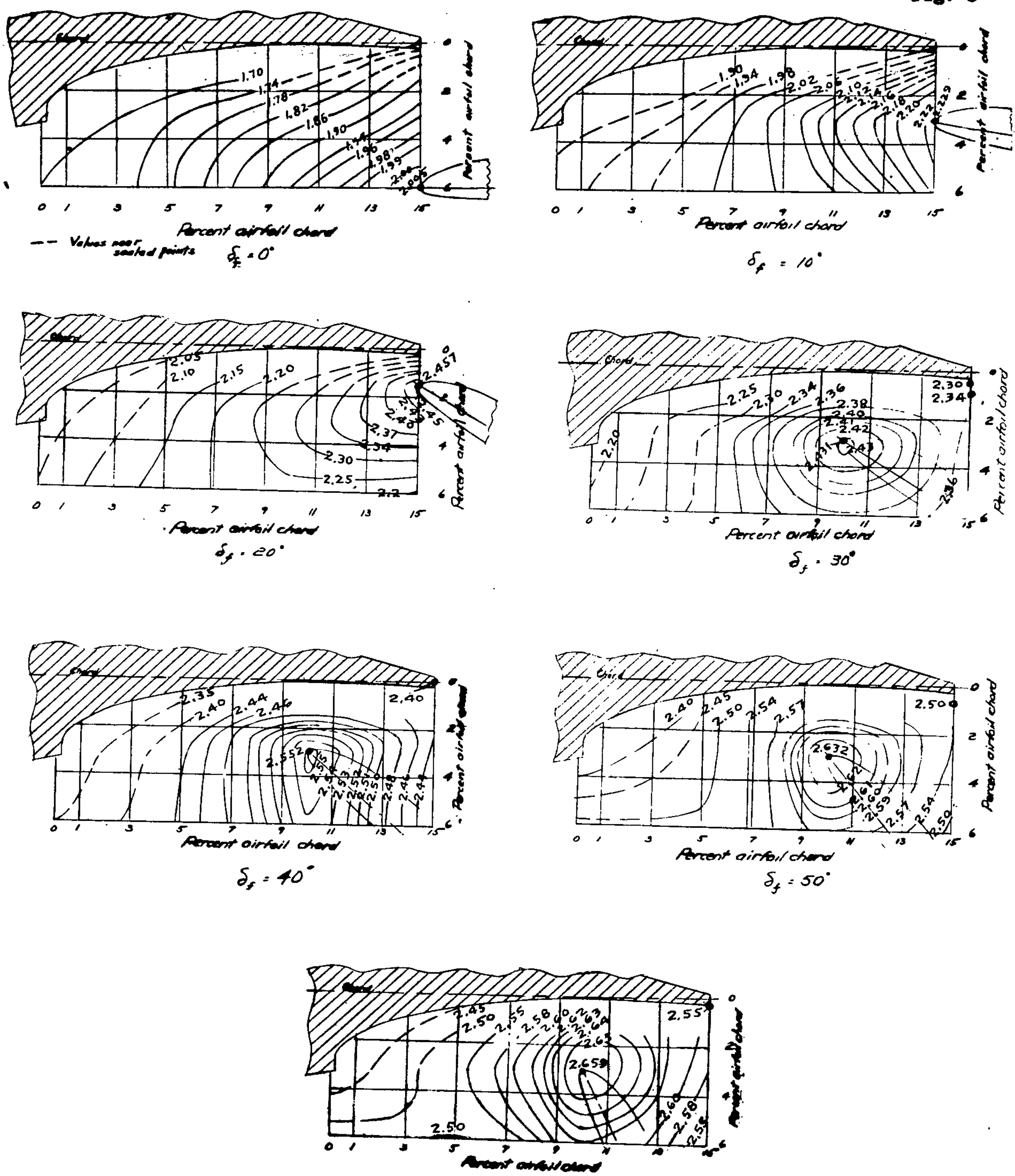

Figure 3.- Contours of flap location for $c_{l_{max}}$; 0.15c balanced split flap.

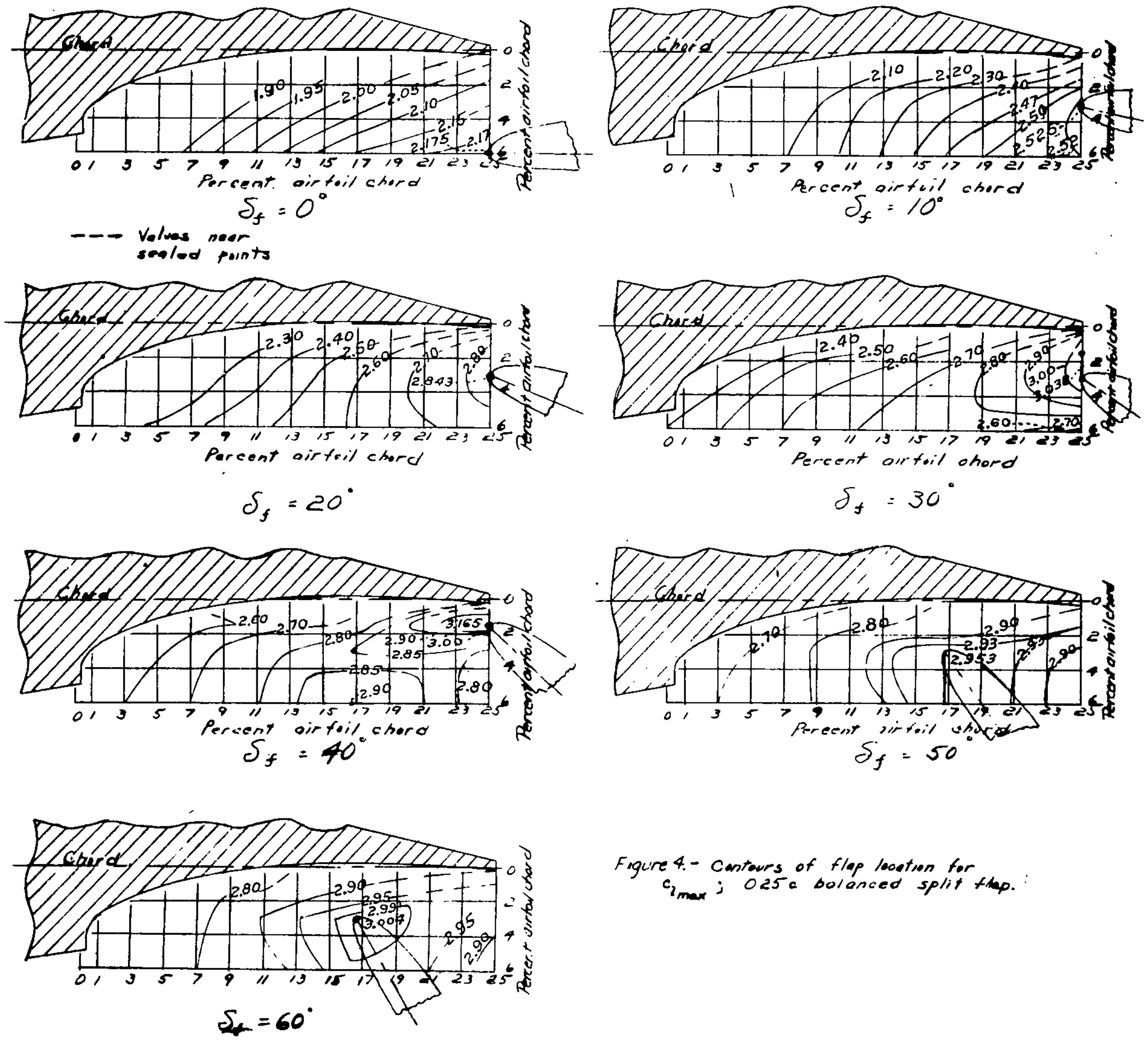

Figure 4.- Contours of flap location for $c_{l_{max}}$; 0.25c balanced split flap.

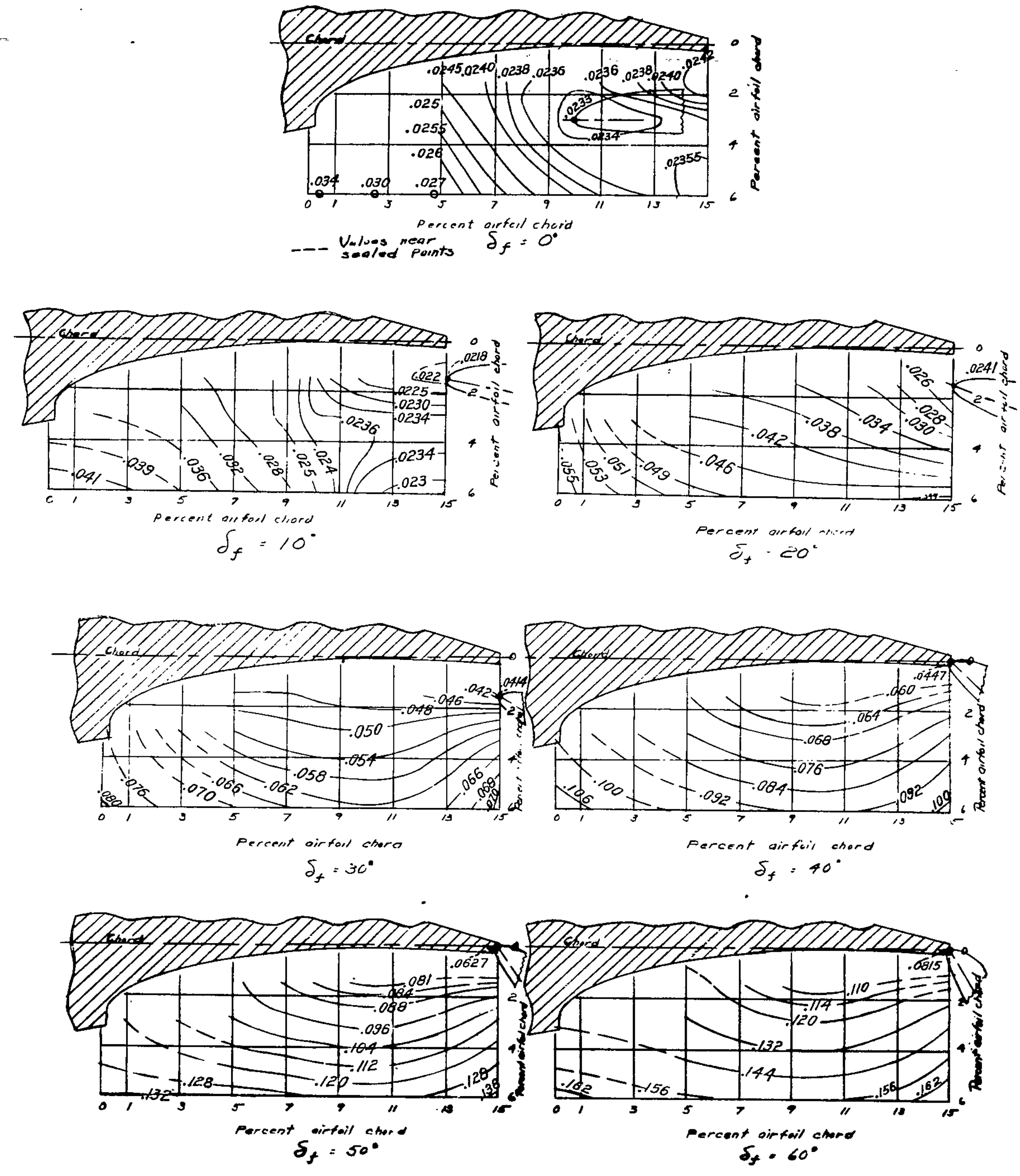

Figure 5.- Contours of flap location for c_{d_0} at $c_l = 1.0$; 0.15c balanced split flap.

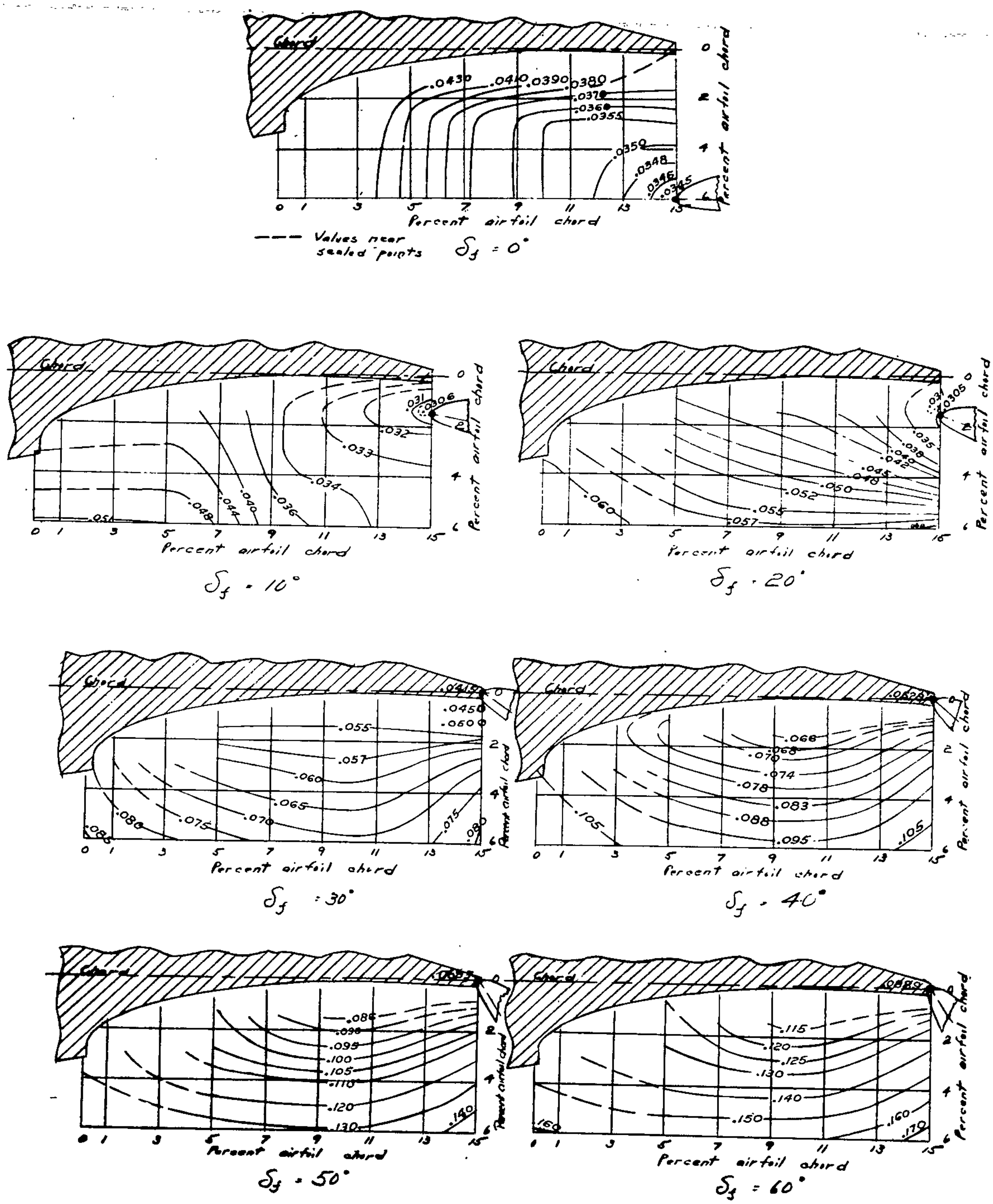

Figure 6.— Contours of flap location for c_{d_0} at $c_l = 1.5$; 0.15 c balanced split flap.

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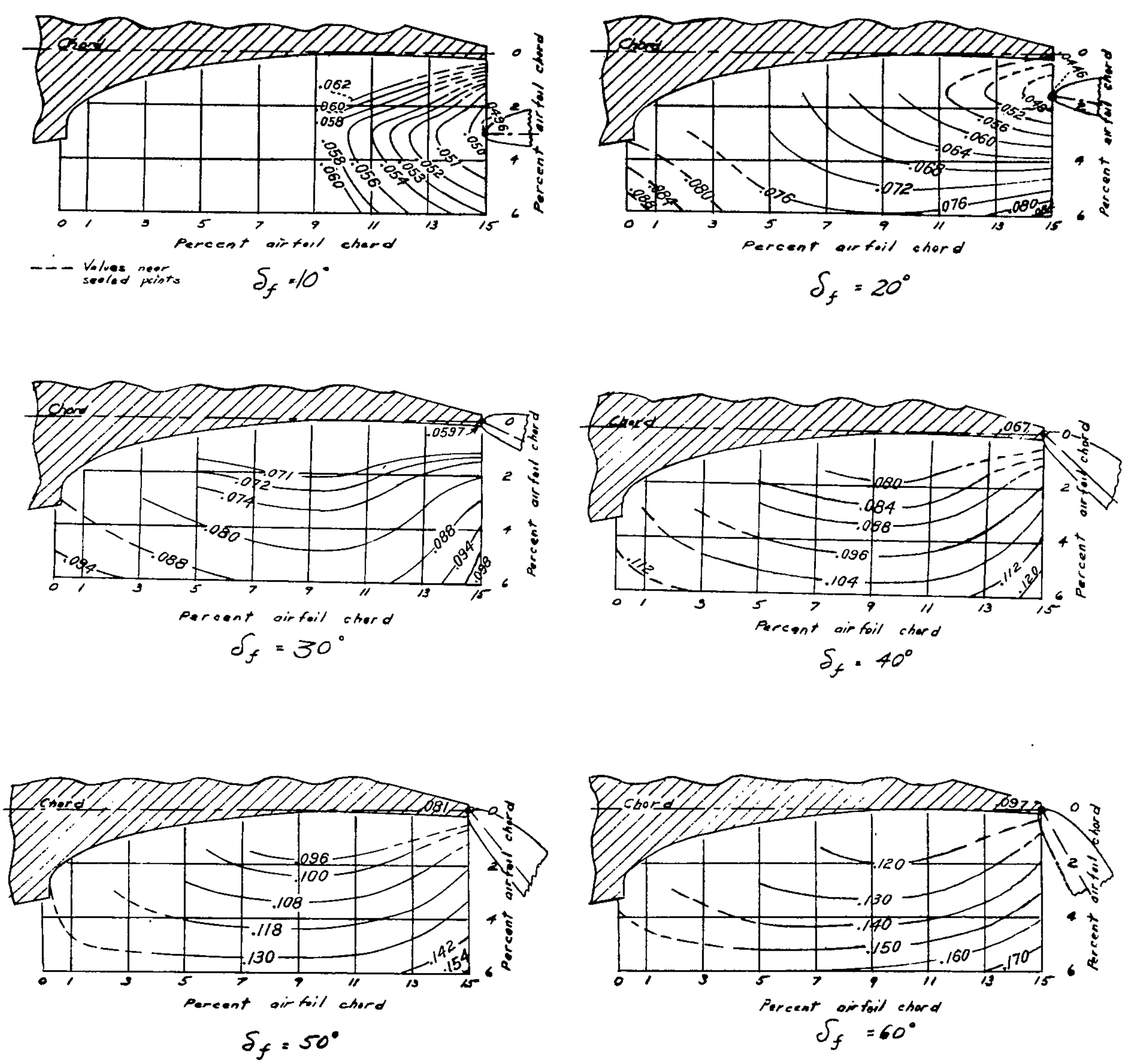
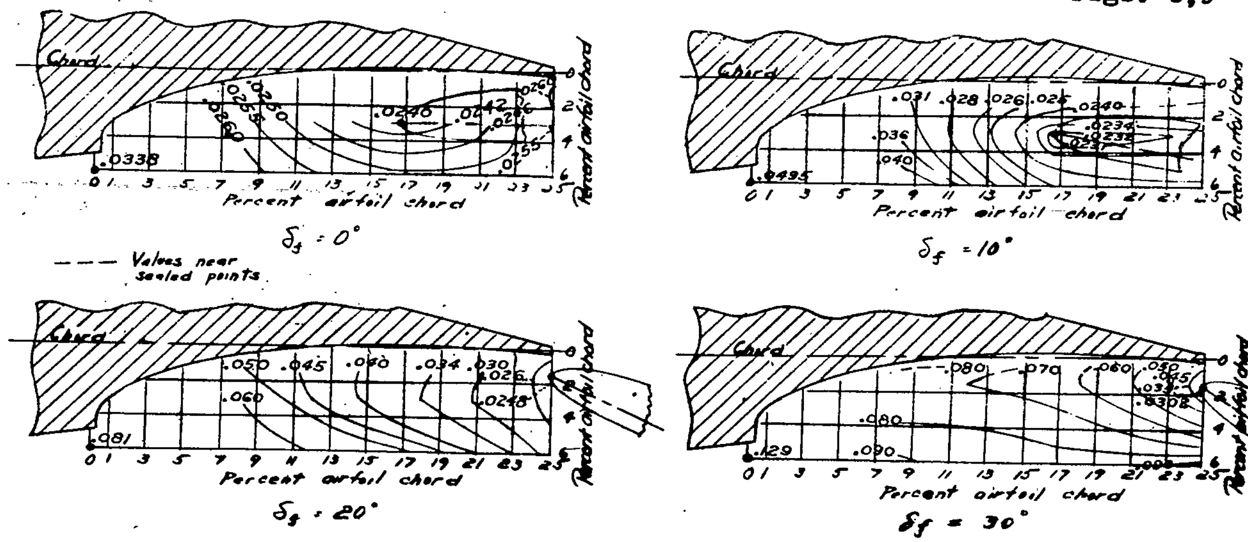


Figure 7.- Contours of flap location for c_{d_0} at $c_l = 2.0$; 0.15c balanced split flap.



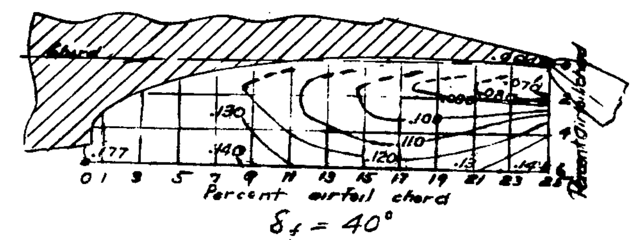
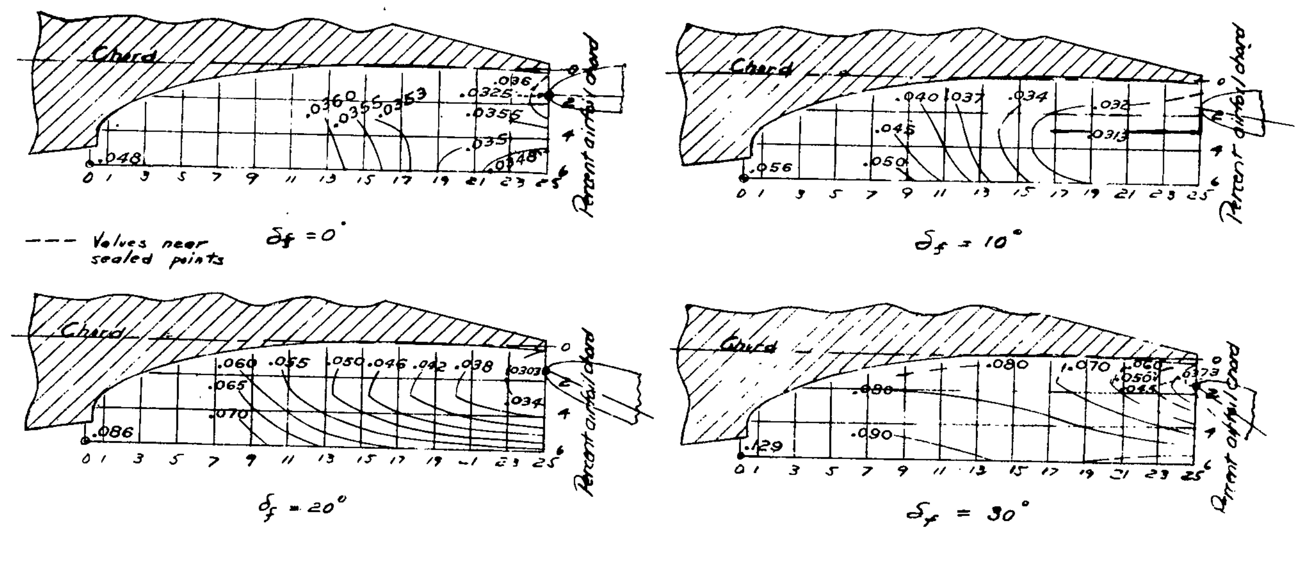


Figure 8.- Contours of flap location for c_{d_0} at $c_l = 1.0$; 0.25c balanced split flap.



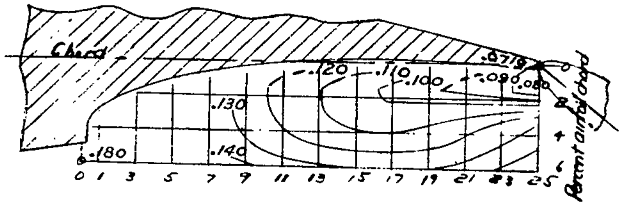


Figure 9.- Contours of flap location for c_{d_0} at $c_l = 1.5$; 0.250 balanced split flap.

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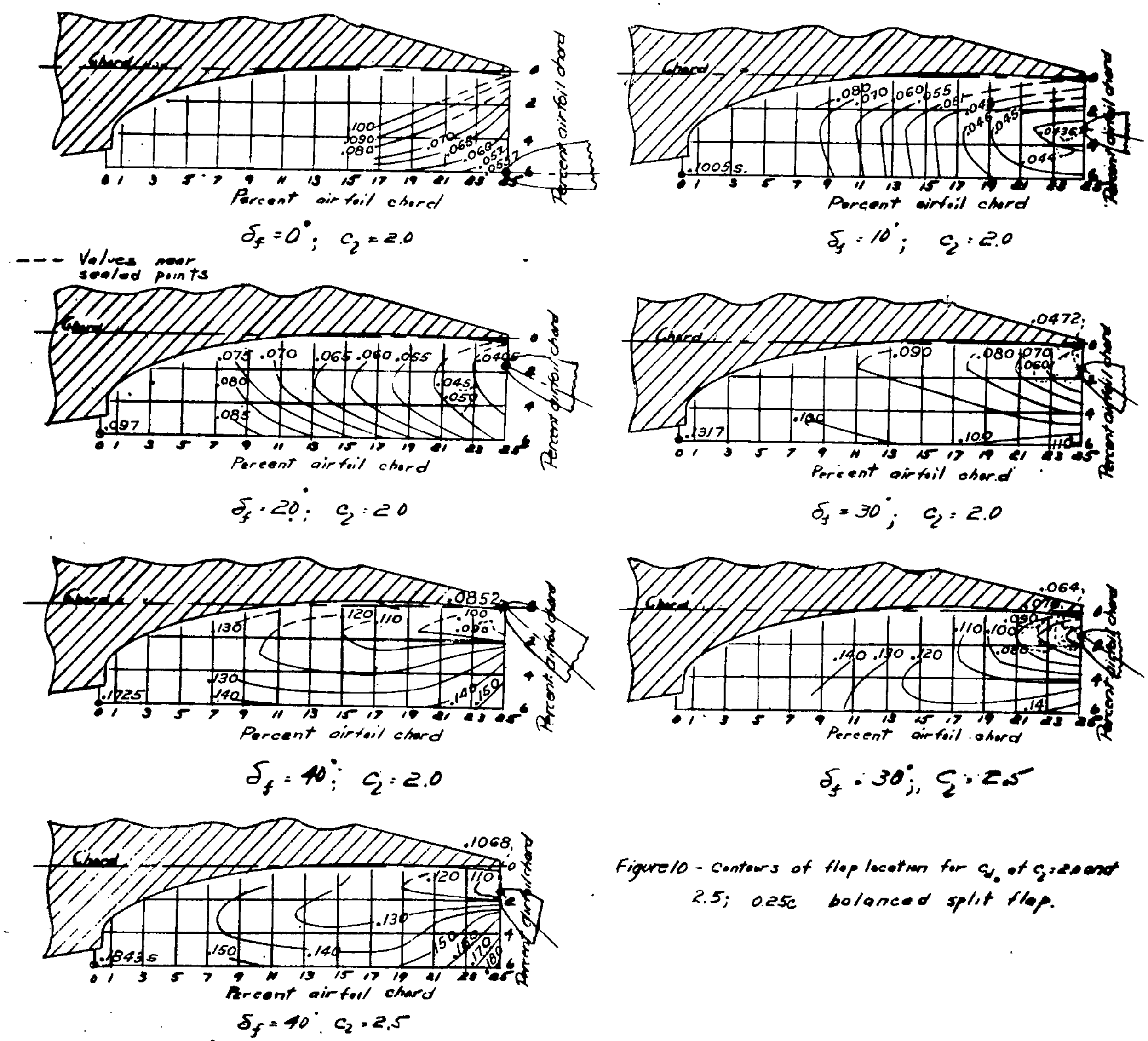


Figure 10 - Contours of flap location for c_{d_0} at $c_l = 2.0$ and 2.5; 0.25c balanced split flap.

Fig. 10

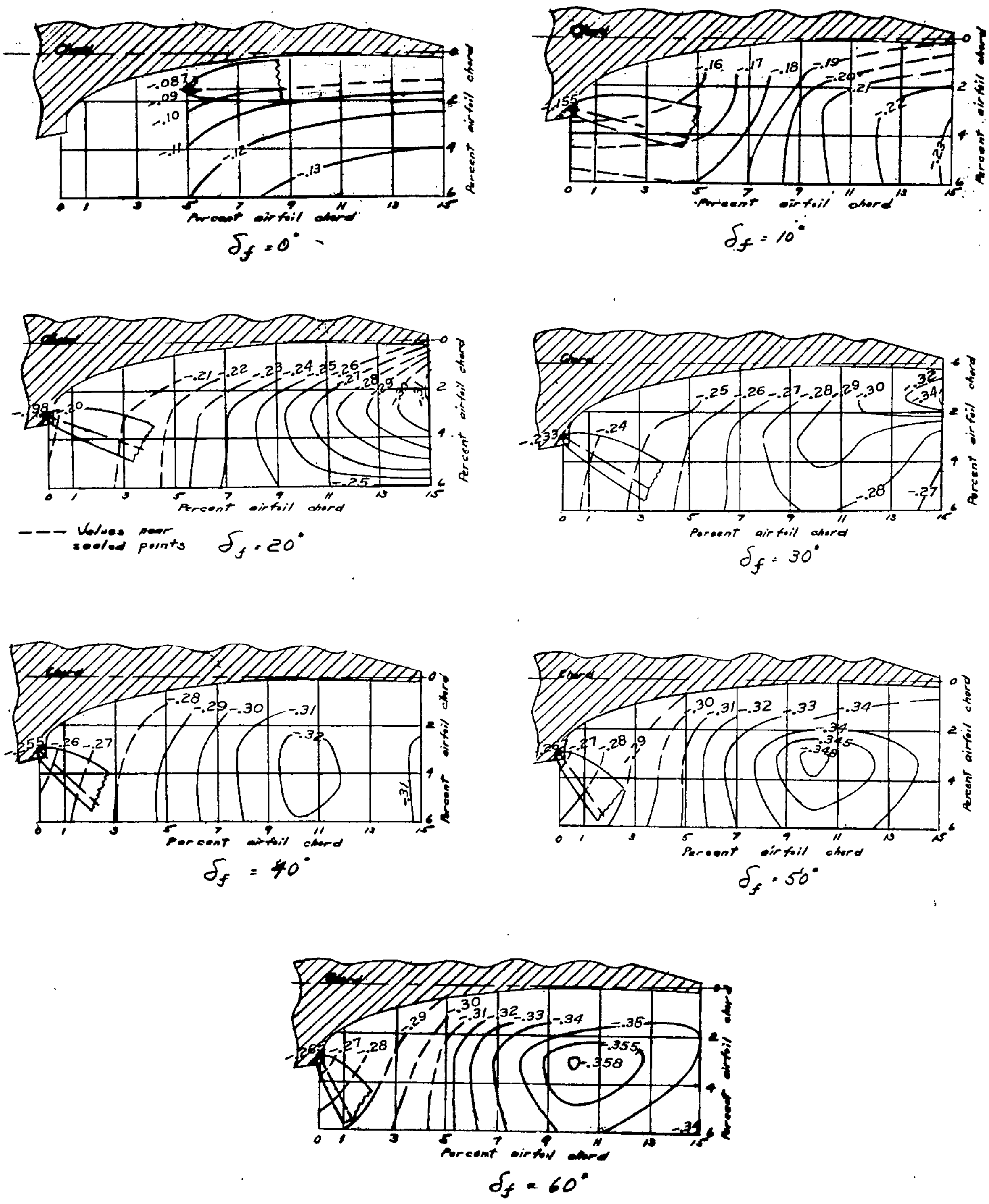


Figure 11.- Contours of flap location for $c_{m(a.c.)}$ at $c_l = 1.0$; 0.15c balanced split flap.

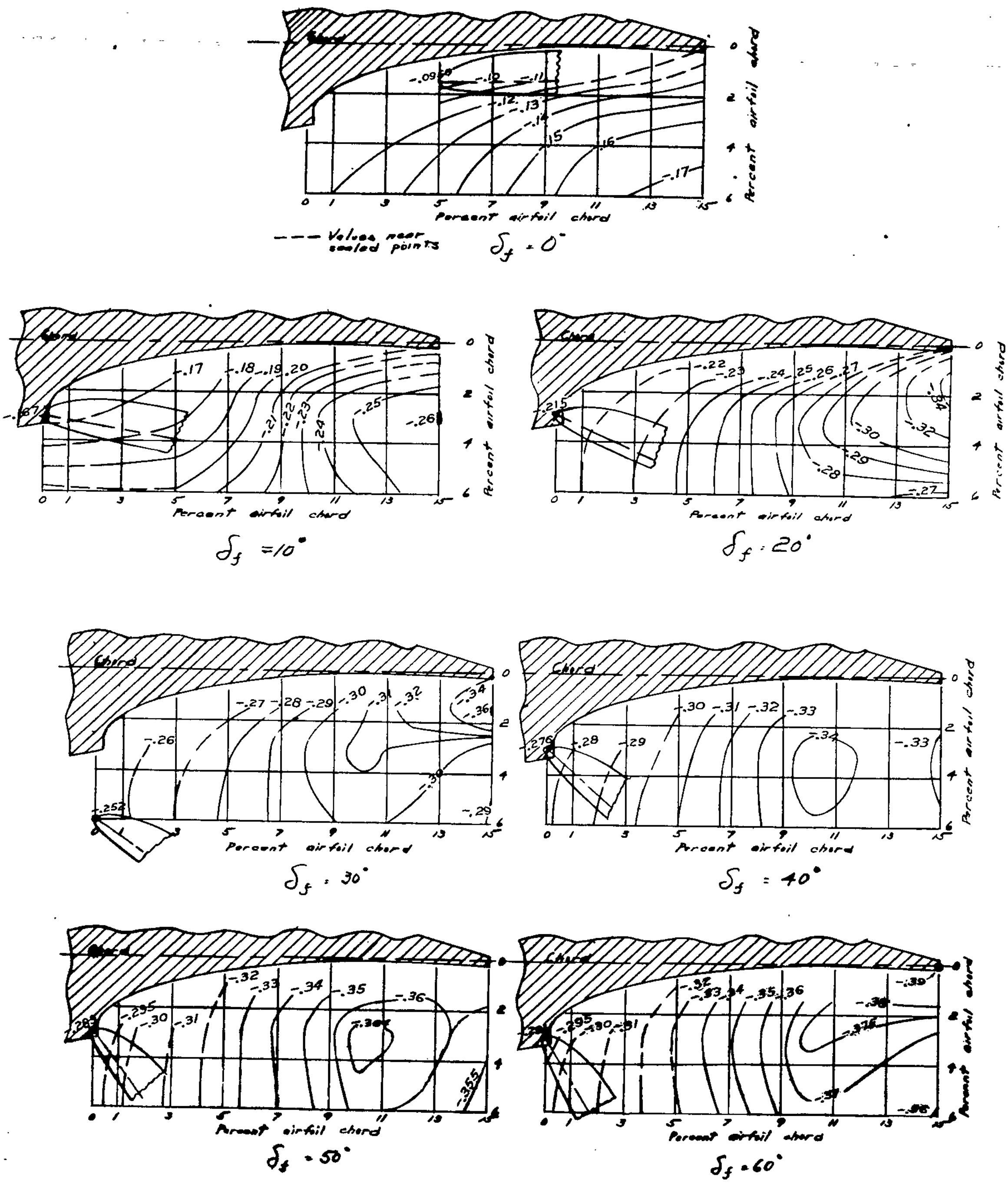


Figure 12.- Contours of flap location for $c_{m_{(a.c.)_0}}$ at $c_l = 1.5$; 0.15 c balanced split flap.

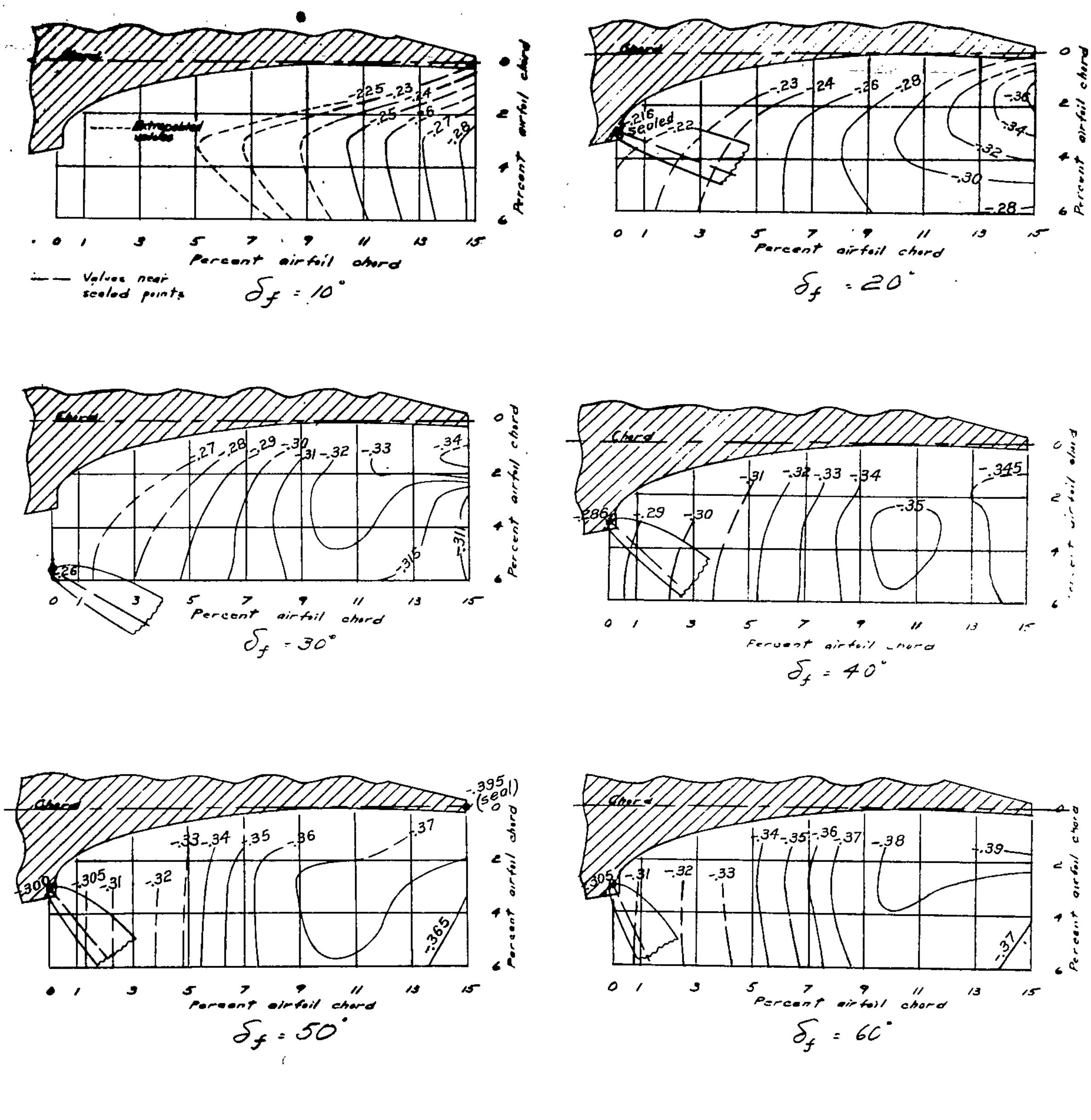
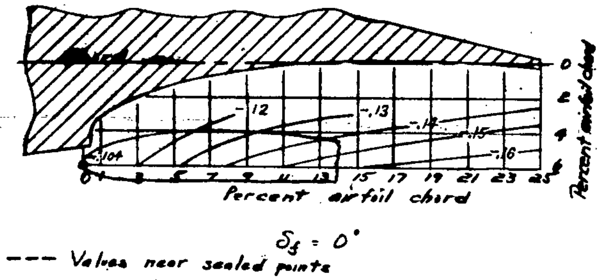
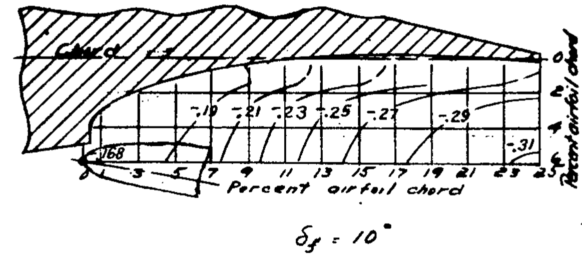
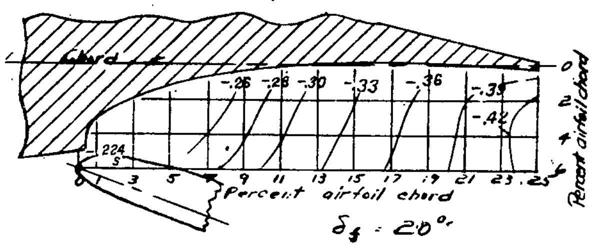
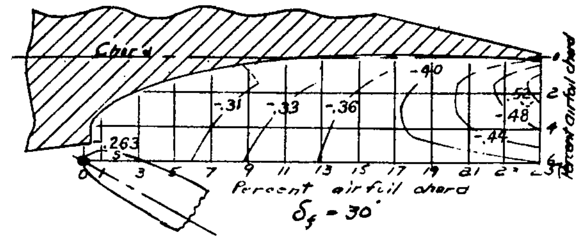


Figure 13.- Contours of flap location for $c_{m_{(ac)_0}}$ at $c_l = .20$; 0.15c balanced split flap.









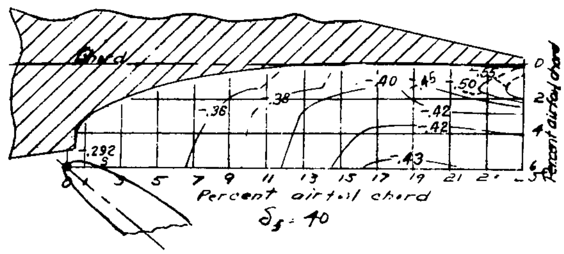
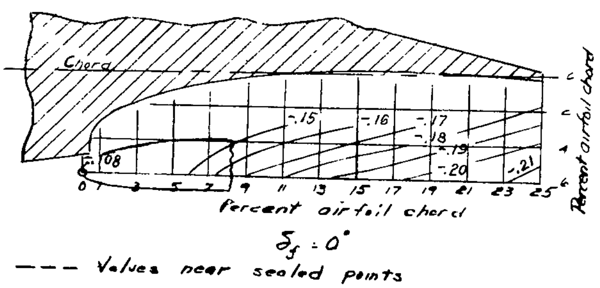
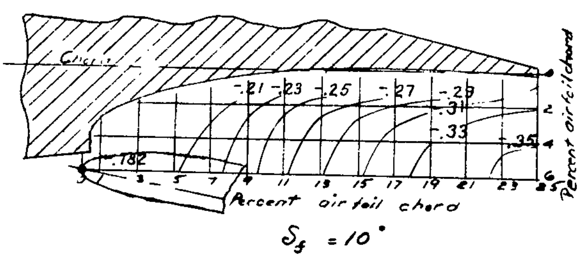
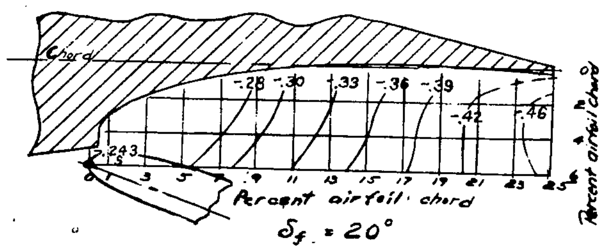
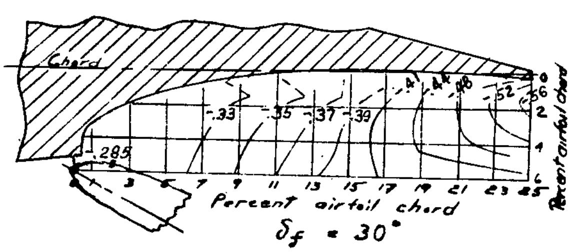


Figure 14.- Contours of flap location for $c_{m_{(a.c.)_0}}$ at $c_l = 1.0$; 0.25c balanced split flap.









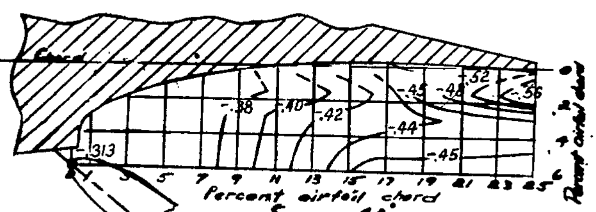


Figure 15.- Contours of flap location for $c_{m_{(a.c.)_0}}$ at $c_l = 1.5$; 0.25c balanced split flap.

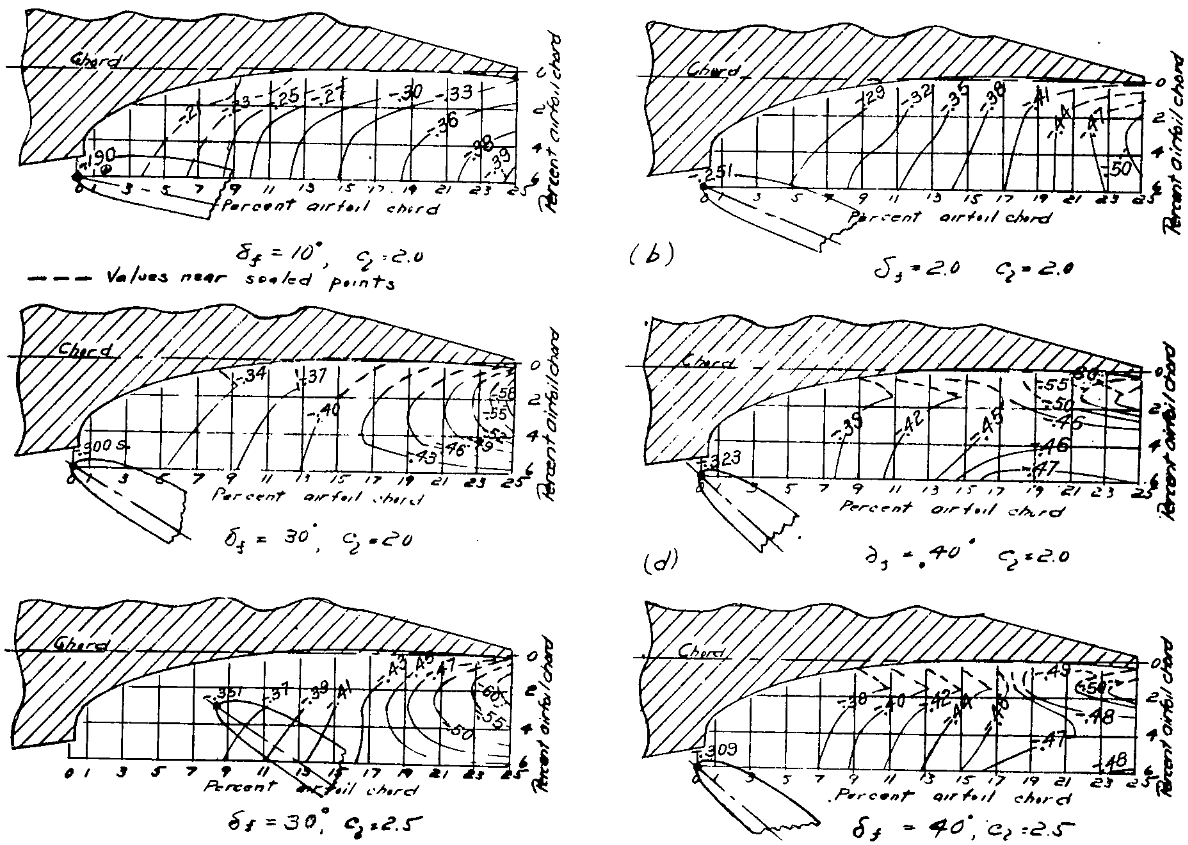


Figure 16.- Contours of flap location for $c_{m_{(a.c.)}}$ at $c_l = 2.0$ and 2.5; 0.25c balanced split flap.

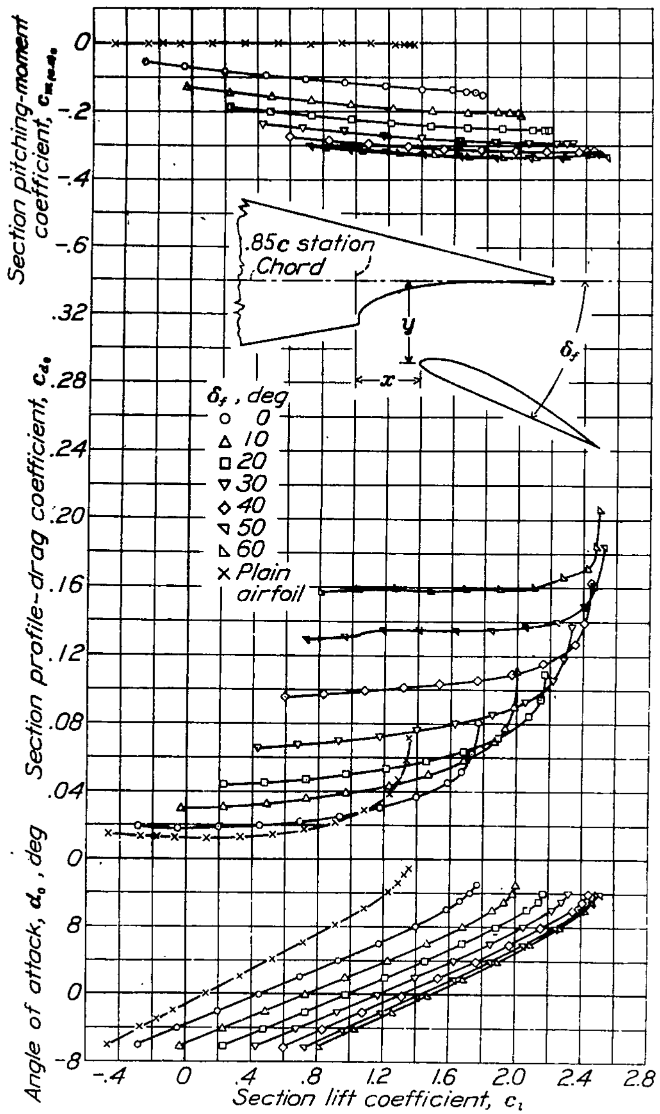


Figure 17.- Aerodynamic section characteristics of NACA 23021 airfoil with 0.15c balanced split flap located at x = 0.05c , y = 0.06c.

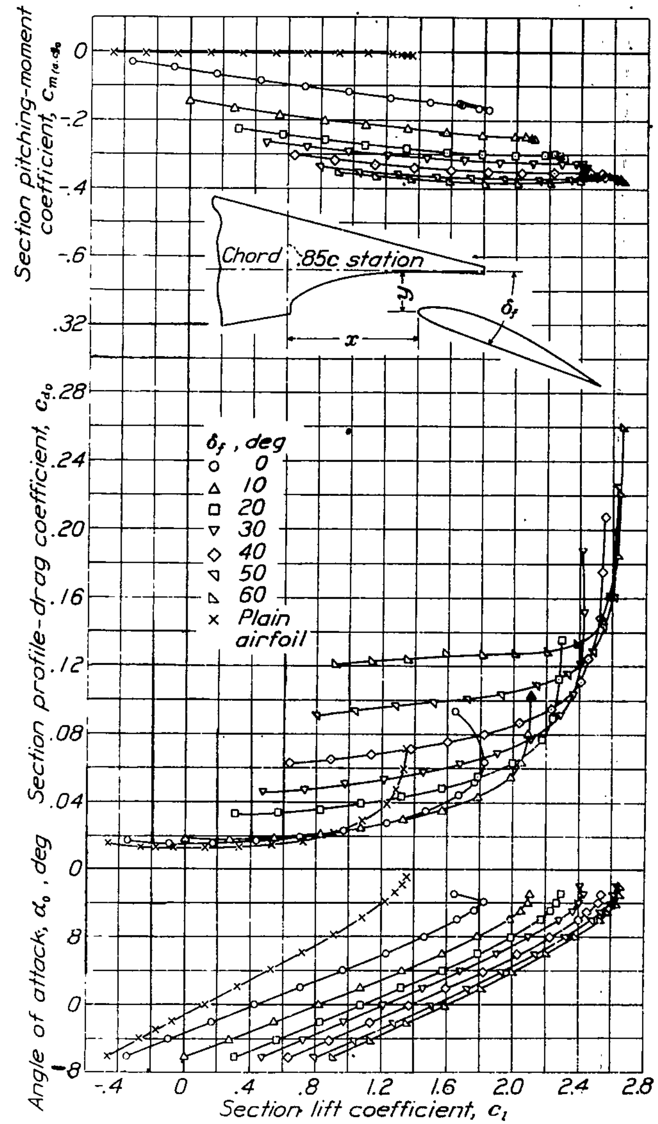


Figure 18.- Aerodynamic section characteristics of NACA 23021 airfoil with 0.15c balanced split flap located at x = 0.10c , y = 0.03c.

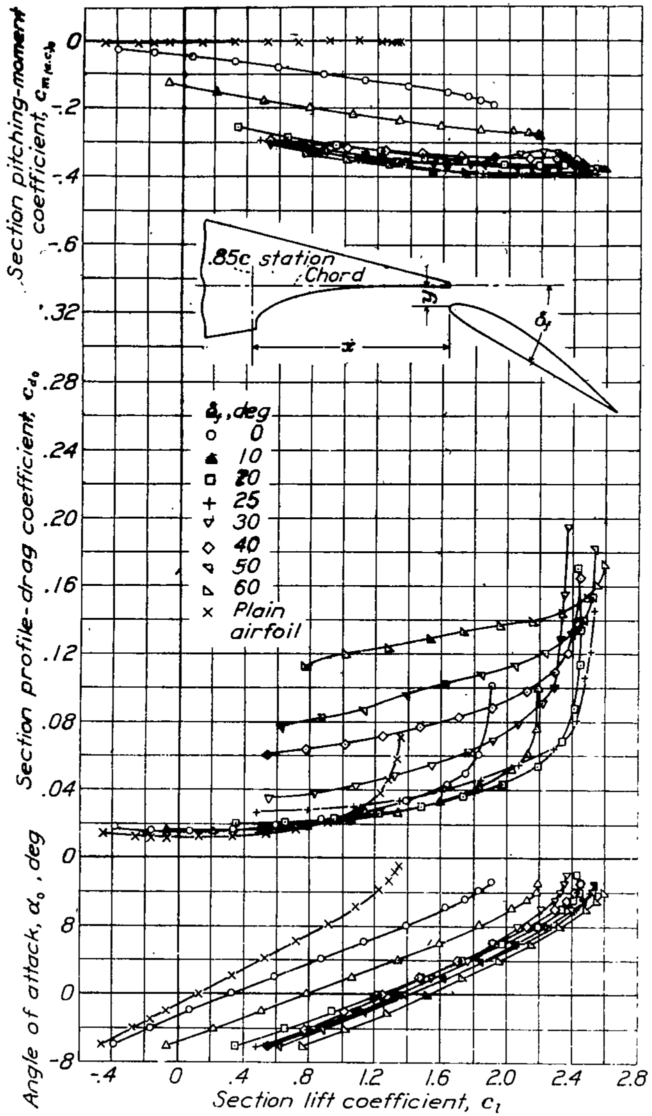


Figure 19.- Aerodynamic section characteristics of NACA 23021 airfoil with 0.15c balanced split flap located at x = 0.15c , y = 0.015c.

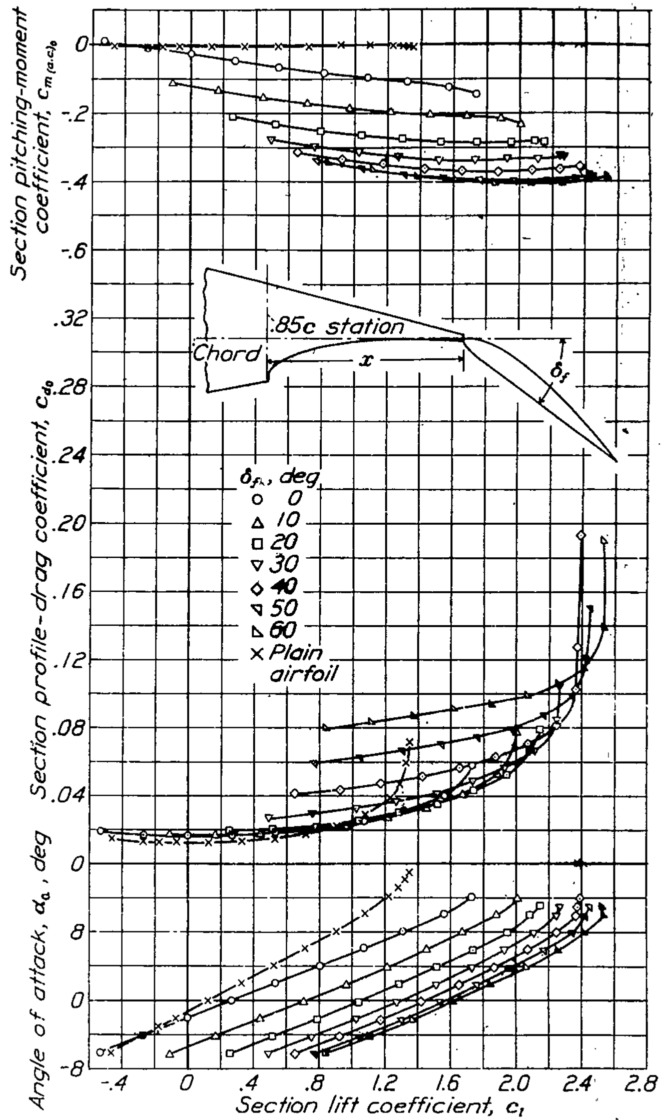


Figure 20.- Aerodynamic section characteristics of NACA 23021 airfoil with 0.15c balanced split flap located at x = 0.15c , y = 0.

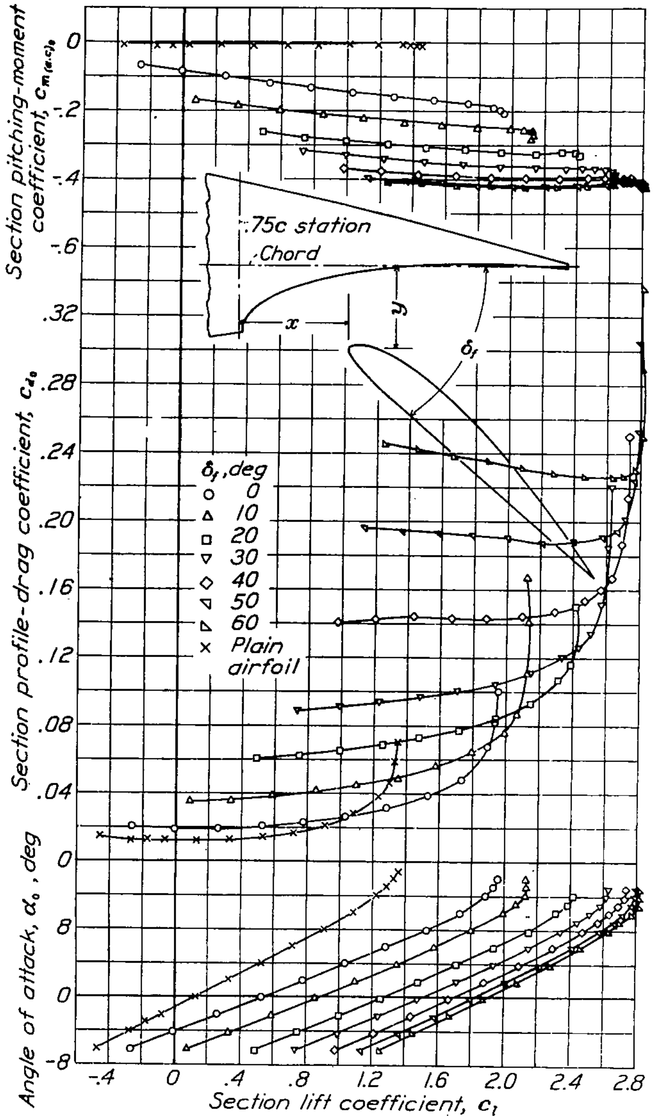


Figure 21.- Aerodynamic section characteristics of NACA 23021 airfoil with 0.25c balanced split flap located at x = 0.0833c , y = 0.06c.

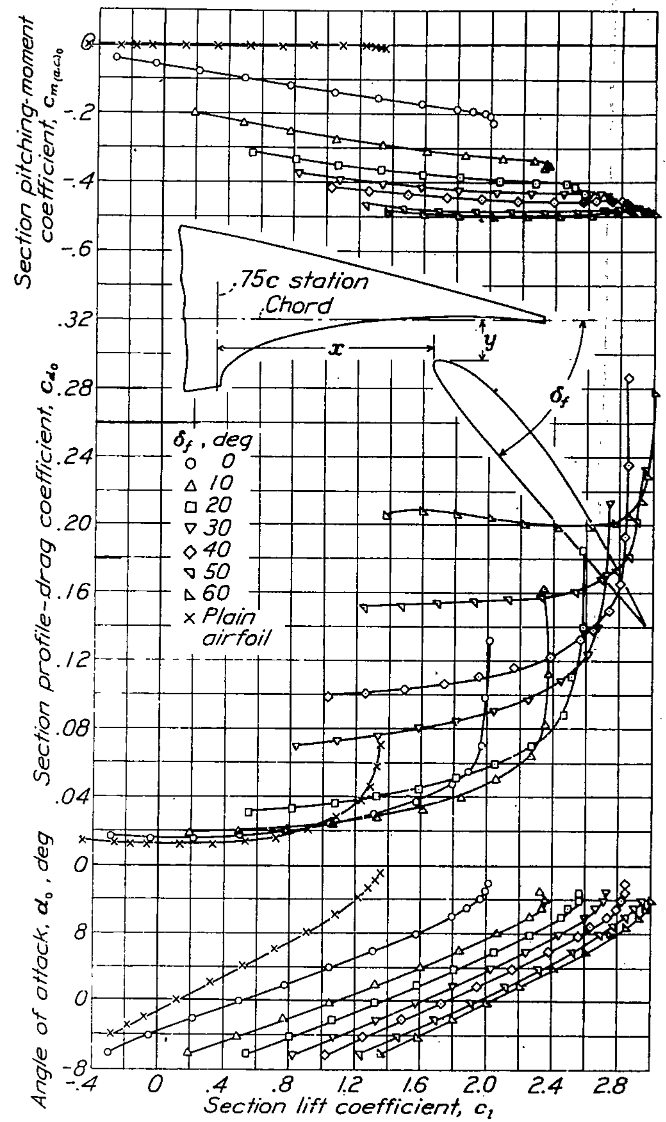


Figure 22.- Aerodynamic section characteristics of NACA 23021 airfoil with 0.25c balanced split flap located at x = 0.1667c , y = 0.03c.

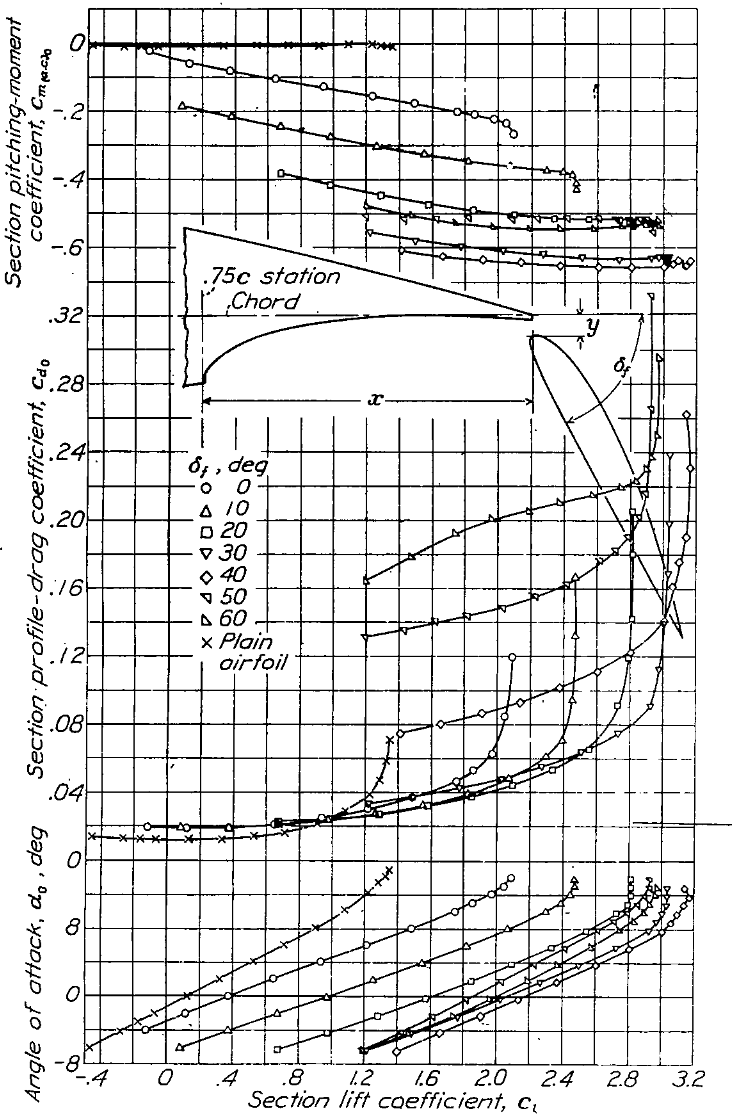


Figure 23.- Aerodynamic section characteristics of the NACA 23021 airfoil with 0.25c balanced split flap located at x = 0.25c, y = 0.015c.

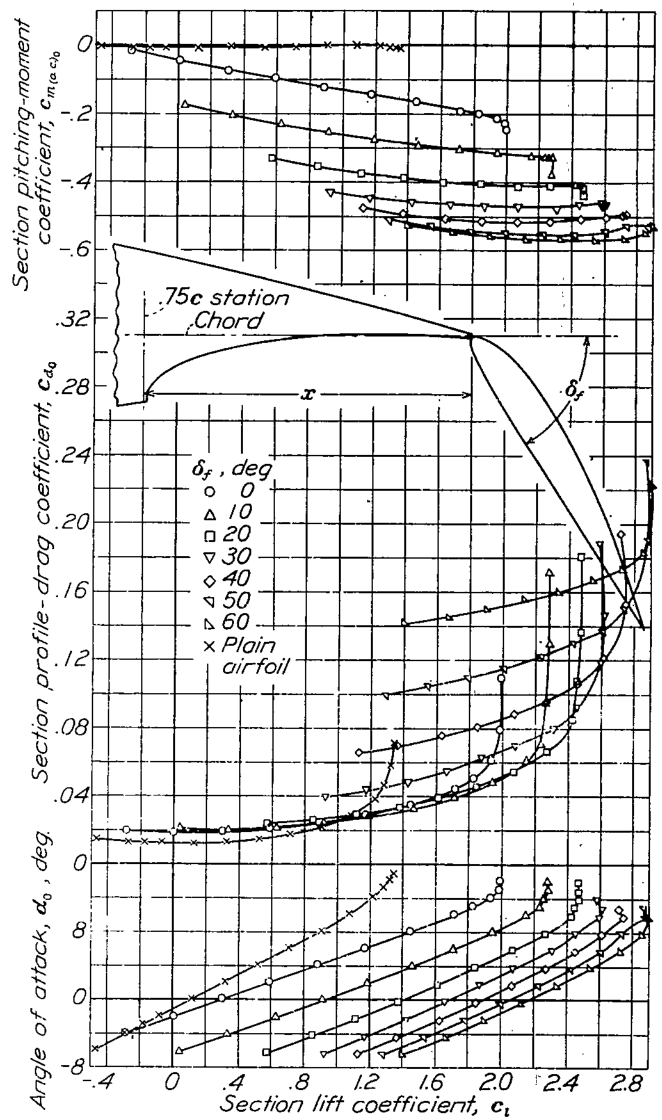


Figure 24.- Aerodynamic section characteristics of the NACA 23021 airfoil with 0.25c balanced split flap located at x = 0.25c, y = 0.

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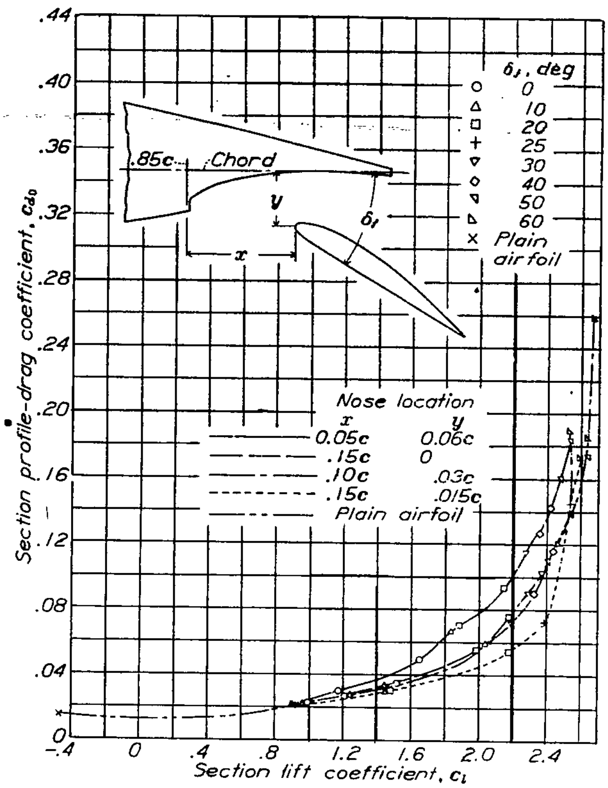

Figure 25.- Comparison of profile-drag coefficients of various arrangements of 0.15c balanced split flap on NACA 23021 airfoil.

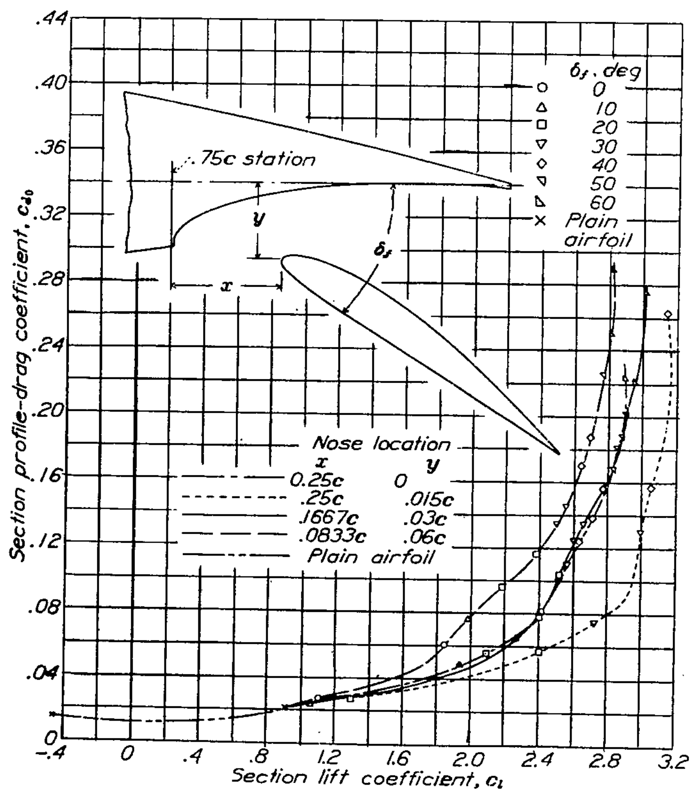

Figure 26.- Comparison of profile-drag coefficients of various arrangements of 0.25c balanced split flap on the NACA 23021 airfoil.

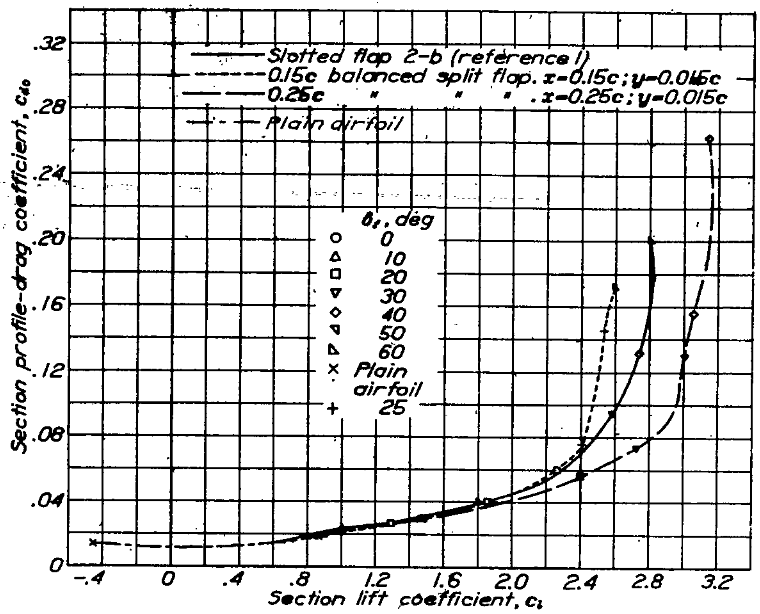

Figure 27.- Comparison of best slotted with best balanced split-flap arrangements on NACA 23021 airfoil.

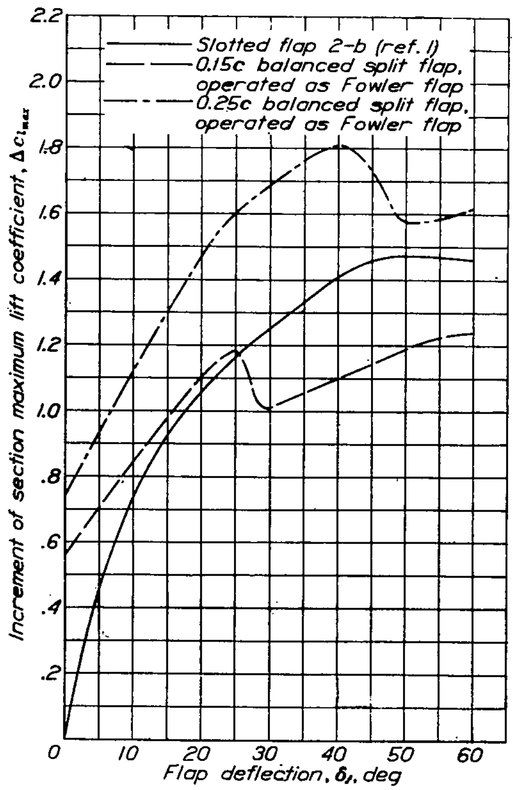

Figure 28.- Comparison of increments of maximum section lift coefficient.